TRANSPORT AND HANDLING

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The NIF Transport and Handling (T&H) Team has the key mission of rapidly replacing optic line-replaceable units (LRUs) (see "Line-Replaceable Units" below) to ensure reliable laser operations. The three-part transportation process involves transporting the precision prealigned optical LRU from the Optics Assembly Building (OAB), the preamplifier module maintenance area, or the airlock to the beamline position; docking the delivery system to the structure or hand-off hardware; and inserting the optic LRU or optic enclosure into the beamline and locking the LRU into position. This must be accomplished while preserving the cleanliness of the optics during the delivery process and preserving the LRU functionality and precision alignment.

LINE- REPLACEABLE UNITS

The design philosophy for the NIF Project is to modularize the laser subsystem components. The line-replaceable unit (LRU) is the key to maximized modularity and efficient operations. Each laser component will be packaged into an LRU for assembling, transporting, installing, and removing the component in an efficient, safe, and cost-effective manner. An LRU is typically composed of a mechanical housing, laser optics (i.e., lenses and mirrors), utilities, and actuators (if necessary).

The use of LRUs provides considerable advantages in terms of time, efficiency, cost, and reliability. Because one of our major goals is to keep the NIF operating continuously, we want to minimize any activities carried out in the beamline that will slow down the process. Taking the modules off-line for maintenance and repair minimizes down time, which results in fewer and shorter maintenance tasks in the beamline. The LRU also enables localized and off-line assembly and alignment activities and allows for more thorough inspections with fewer time constraints, which makes the laser more reliable.

Inventories can be simplified by using LRUs because of reduced part counts, and storage flexibility can be increased with the use of standardized packaging. We are trying to make each package as similar as possible to minimize the number of spare parts needed. In addition, it simplifies storage to have standardized slot sizes for each module. Another advantage of this standardization is that employees become more effective if they deal with fewer types of motors, for example, rather than having to learn the intricacies of 20 different types.

The use of LRUs also minimizes the exposure of beamlines to the laser bay environment, which is far less clean, and it maximizes the cleanliness of the beamline by reduced operator contact. The interior of the beamline is maintained as Class 100 to protect the optics inside from particles. Minimizing the contact of the beamline with outside environments or operators also helps reduce the possibility of damage to the laser's optical components.

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Introduction

There are five types of delivery systems (Figure 1) needed for the NIF Project: bottom loading, side loading, top loading, switchyard loading, and target bay loading, depending on the requirements of the LRU type, its physical location, structural and other constraints, and the interface requirements. T&H is responsible for installing 34 different types (Figure 2) of optic LRUs that have various locations in the laser bay, the switchyards, and the target area (Figure 3).

The design requirements for T&H include developing delivery system designs for the optic LRUs; building and testing the first-off systems; procuring, fabricating, and assembling the NIF LRU delivery system hardware; inspecting and verifying delivery systems hardware; and delivering optic LRUs according to the plan for start-up activities and long-term operations

Transporter

The laser bay transporter is the "get it there" part of the LRU delivery system (Figure 4). One laser bay transporter design is the basis for all three LRU insertion systems (bottom, top, and side loading) in the laser bay. The transporter transports, lifts, and positions the canister or skid at docking points on the laser structure. It must deliver LRUs to over 2,700 specific locations inside the concrete structures.

Due to clearance, alignment, and weight requirements, the transporter must be customized. The size requirements of the loads in combination with the facility opening dimensions require that the transporter lift on the outside of the canister instead of from the bottom, that it have a 6-ft fork spacing, and that it have a transport guidance system. The tight transporter clearance with the structure in some LRU locations limits the outside dimensions of the transporter as well. In the Title II Design phase, we are working closely with vendors to develop the optimum solution to transporter requirements.

Title II Activities

Title II engineering priorities include completing transporter specifications, evaluating tradeoffs between guidance systems, finalizing docking and alignment designs, down-selecting transporter

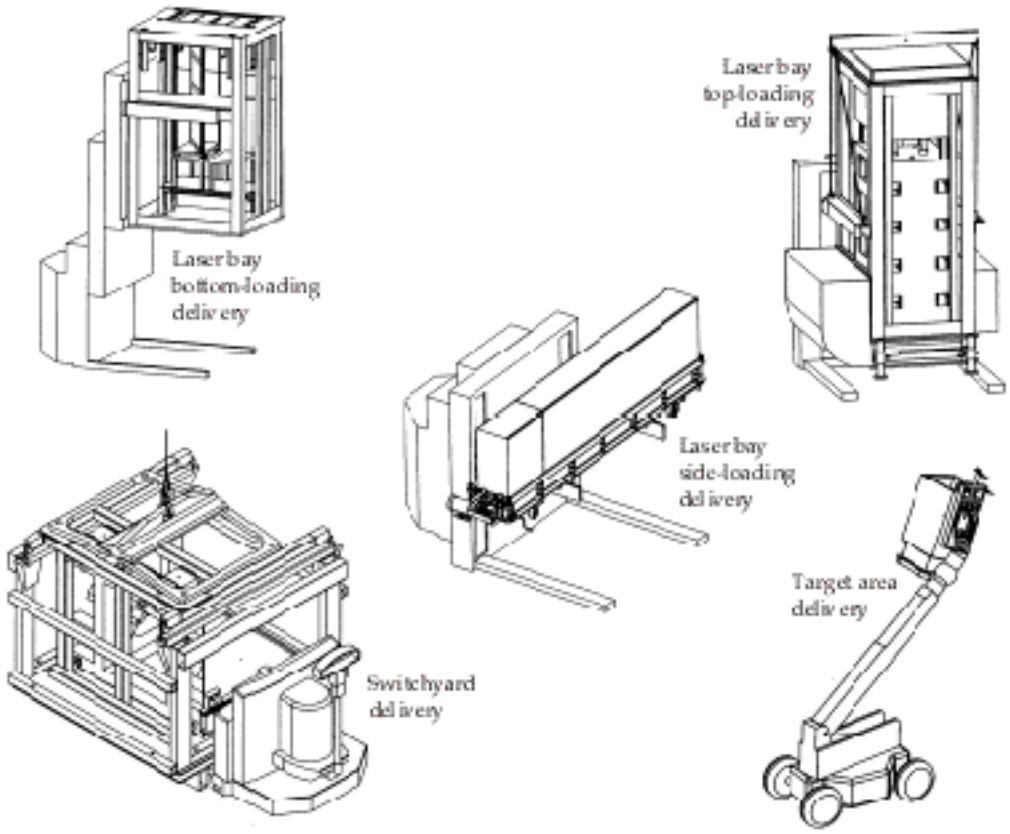

FIGURE 1. Five T&H delivery systems. (40-00-0997-2078pb01)

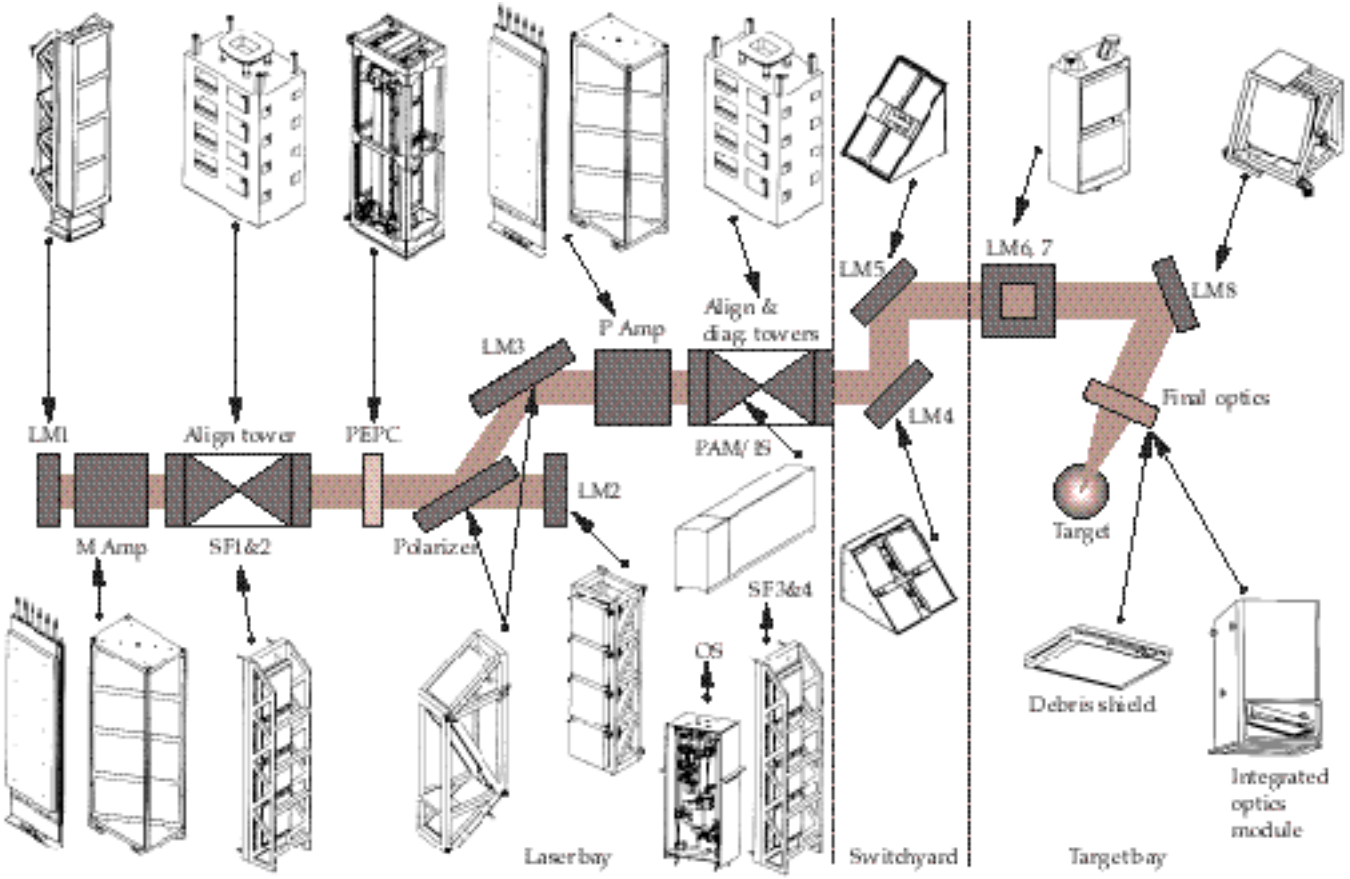

FIGURE 2. The 34 types of optic LRUs (many of the 20 types shown have multiple orientations, making a total of 34 distinct types).
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FIGURE 3. The optical LRU delivery locations.
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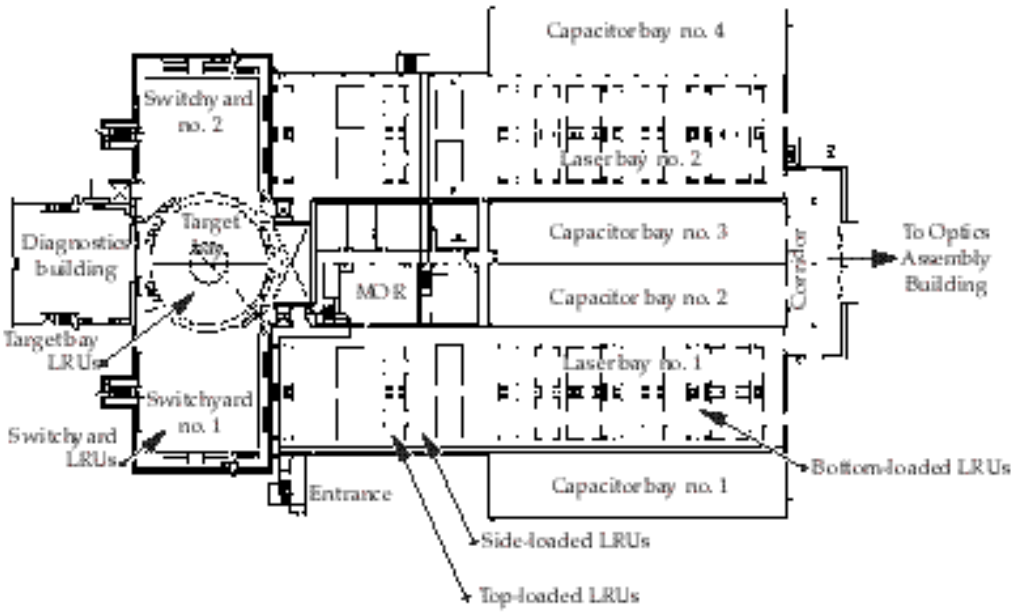

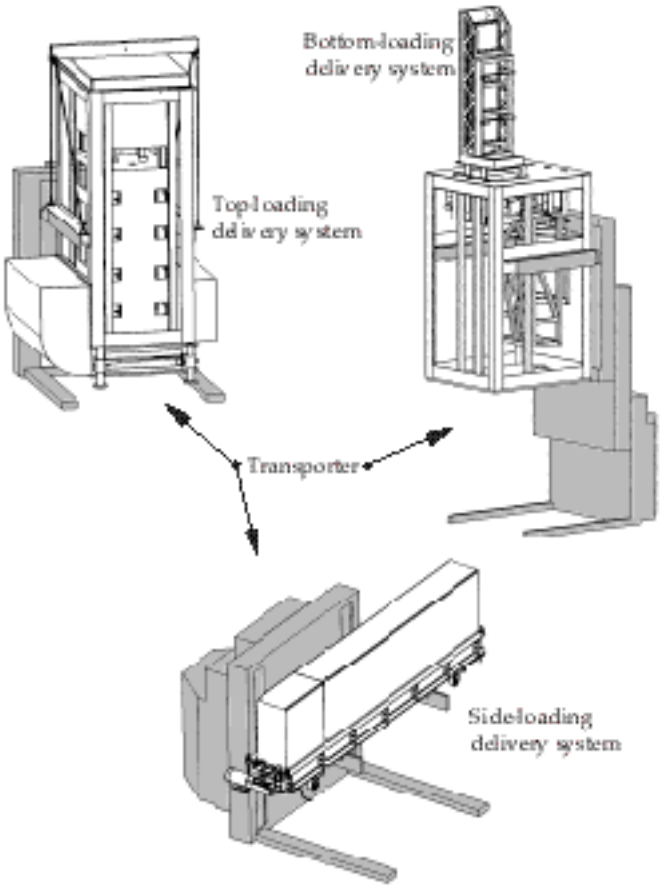

FIGURE 4. The laser bay transporter. (40-00-0997-2081pb01)

vendors, developing a controls interface, evaluating safety and egress issues, and determining storage and maintenance locations.

Bottom-Loading Delivery System (BLDS)

The requirement of the BLDS is to transport and install 18 different types (with a total of 2,736) of bottom-loaded optic LRUs. Each LRU has a unique geometry (Figure 5) with different footprints and insertion envelopes. The LRUs have different beamline gas environments, vertical travels, kinematic mounts, and utilities connections. All but the flashlamp require a cleanliness level of 50. All LRUs require a bundle spacing of 1,500 mm.

There are three BLDS canisters: universal, amplifier, and flashlamp. All three will use the same lifting systems and virtually the same canister frame design.

The docking mechanism will use kinematic mounts to align the canister under the laser beam structure. There are three different types of installation processes: single-stage, periscope multistage, and spatial filter three-axis installation (Figure 6). The process for bottom-loading single-stage LRU installation is as follows:

An LRU is inserted into the BLDS canister from the OAB. It is then moved by an automated self-guided vehicle (AGV) transporter to the LRU's insertion location under the laser beam structure. The AGV then lifts the canister to within a few millimeters of the structure and activates its compliance system. Continuing with the lift, the canister docks to the structure by having its kinematic docking balls self-align to the receivers in the structure. The canister's pneuma seal (inflatable seal) is activated, sealing around the laser beam structure cover. The cover is removed by the cover removal system in the canister. The vertical ball screw insertion system then lifts the LRU to a height in the beam structure where the internal kinematic mounts activate and hold the LRU in place. The carriage of the insertion system then lowers down into the canister. The cover removal system replaces the cover in the structure and seals the canister. The pneuma seal is deflated, and the canister is lowered and returned to the OAB.

The spatial filter installation requires the "y" axis transaction of the single-stage lift followed by a translation in the "x" axis to complete the installation.

The periscope installation assembly, the most complex type, requires the use of spacers to lift the LRUs to the required heights (Figure 7). After the periscope LRU is lifted by the carriage to the top of the canisters, a shelf mechanism is activated to capture the LRU. The carriage is lowered back down, and the first spacer is translated onto it. The spacer, with the LRU above it, is then lifted to the shelf mechanism, which holds it. When the carriage is lowered again, a second spacer is inserted and lifted, extending the LRU to the height required for installation inside the beam enclosure.

The Amplifier Module Prototype Laboratory (AMPLAB) is currently testing a prototype vehicle referred to as the maintenance and transport vehicle (MTV). Although the MTV is not configured to transport and install all bottom-loaded LRUs, T&H is leveraging off the experience from the MTV and will gain useful cleanliness data from the insertion and removal of the amplifier and flashlamp LRUs.

Analyses are being done on all critical elements of the delivery system. Prototyping and testing will verify and validate all principles. A Class 100 environment will be maintained inside the canister, so cycle testing for cleanliness will be an integral part of the prototyping effort. The alignment of the delivery system to the beam enclosure

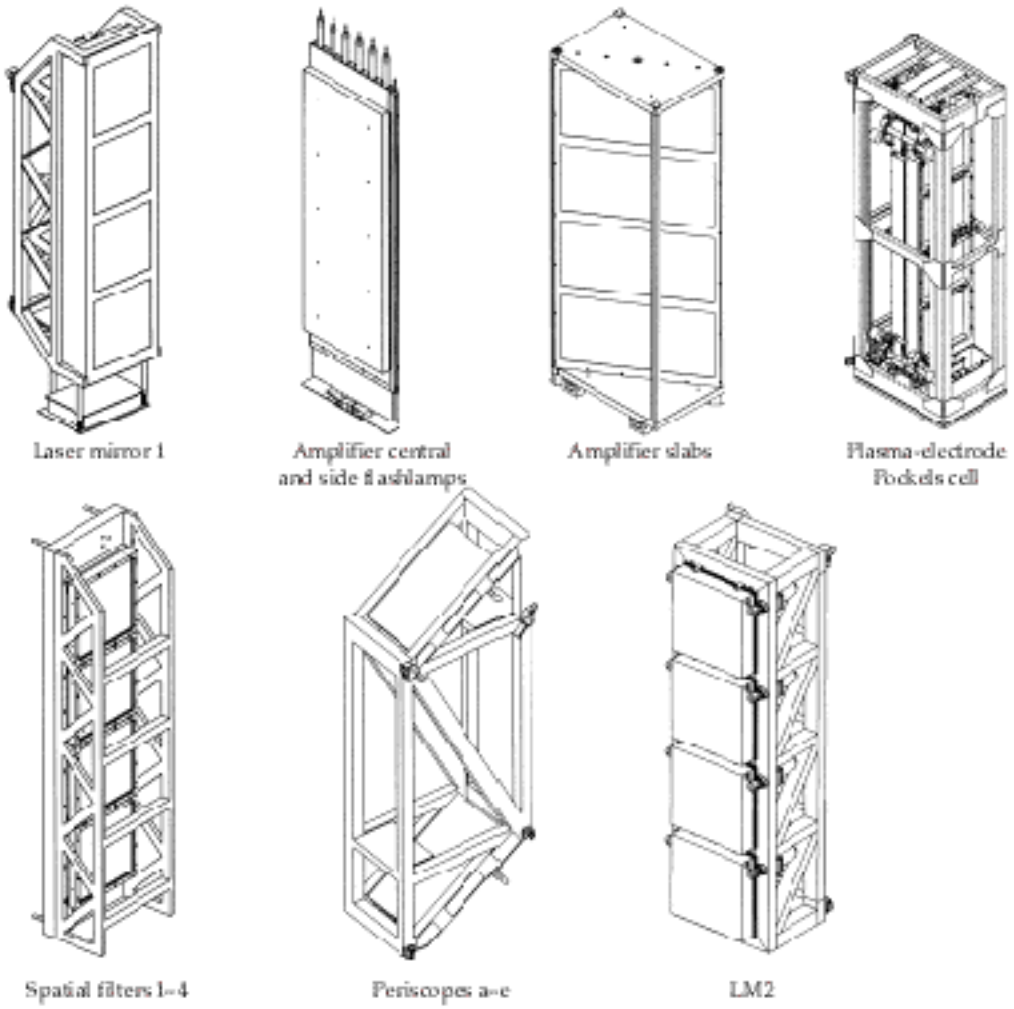

FIGURE 5. The unique geometry of the LRUs.
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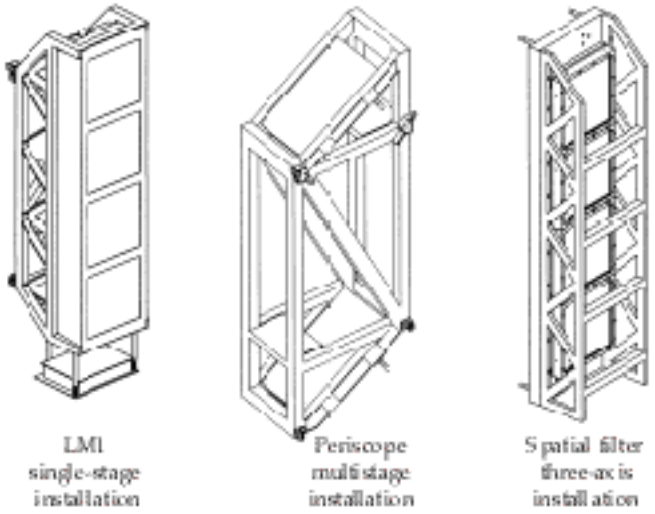

FIGURE 6. Three types of installation processes.
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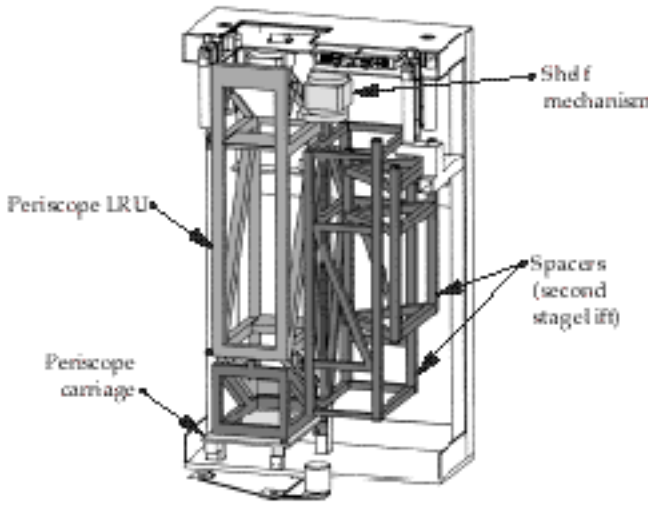

FIGURE 7. The periscope installation assembly.
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structures and designing the insertion mechanism are two important challenges for Title II Design.

Title II Activities

During Title II, we will build and test prototype subsystems, including the canisters, insertion mechanisms, control systems, and the AGV transporter. As a result of our prototyping efforts, analysis, and interface issues, we will refine and complete the delivery system design.

Top-Loading Delivery System

Top-loading (TL) LRUs are located in the transport spatial filter and the cavity spatial filter center vacuum vessels. These are top loaded to optimize the use of space in the laser bays.

TL LRUs are all the same size, require a Class 100 clean environment, and use the same transporter as the bottom- and side-loading systems (Figure 8). The laser bay transporter moves the TL canister from the OAB to the laser bay; the laser bay crane lifts and docks the canister to the vacuum vessel; and the canister cleanly transfers the LRU into and out of the vacuum vessel.

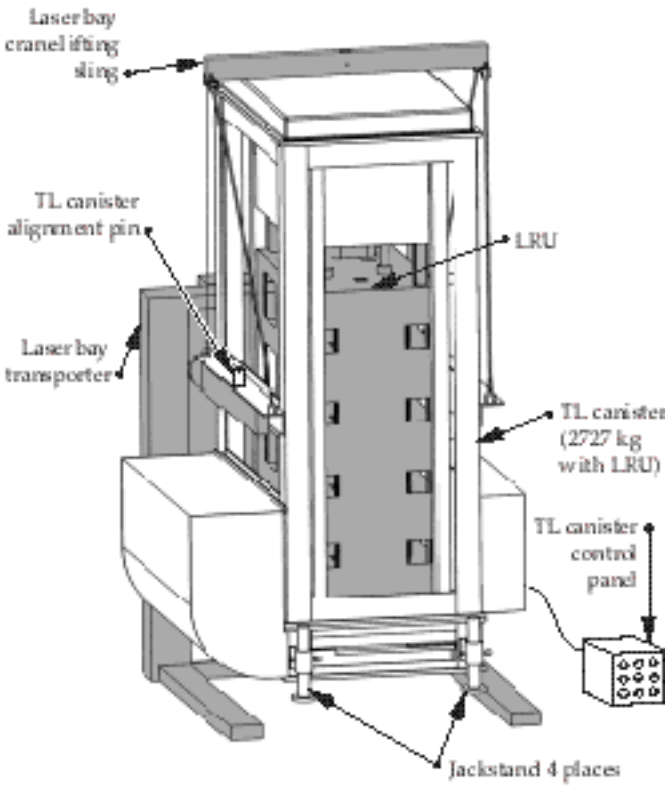

FIGURE 8. The top-loading delivery system.
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The vacuum cover removal mechanism must translate and rotate due to the cover size. The latching mechanism (protruding from the canister bottom cover) engages the vacuum vessel cover as the canister is docked, and then a scissors mechanism lifts the vacuum vessel and canister covers (simultaneously) prior to translation and rotation. The LRUs are lowered onto kinematic mounts at the bottom of the vacuum vessel, the vacuum vessel covers are replaced, the canister covers are disengaged, and the TL canister is undocked.

During Title I , we have developed an initial TL delivery system design, quantified vibration and shock requirements, defined personnel safety issues, and developed a scheme to deal with delivery system failures during transport.

Title II Activities

During Title II, the TL canister mechanisms will be prototyped and tested to mitigate risks. Structural and dynamic analyses will be performed. We will analyze the TL delivery system to meet LLNL seismic safety standards. We will support the specification and procurement of the laser bay transporter.

Side-Loading Delivery System

All side-loading (SL) LRUs are located in the transport spatial filter area. There are three SL LRUs and two different delivery systems (Figure 9): the output sensor delivery system and the SL delivery system.

The output sensor transporter is a commercially available manual lift truck with custom-designed lifting forks. It lifts and positions the output sensor for installation. The output sensor is then manually positioned onto its kinematic mounts, and the utilities are connected at the bottom after installation.

The SL delivery system, which consists of the laser bay transporter and the SL skid, is used to load LRUs into and out of the preamplifier module (PAM) support structure (PASS). The laser bay transporter positions and aligns the SL skid for docking to the PASS. The docking mechanism engages the PASS for alignment and support. The SL skid is used to transfer the LRUs on and off the precision LRU support rails.

Title II Activities

During Title II, the SL skid will be prototyped and tested to ensure reliable performance. Structural and dynamic analyses will be performed to ensure

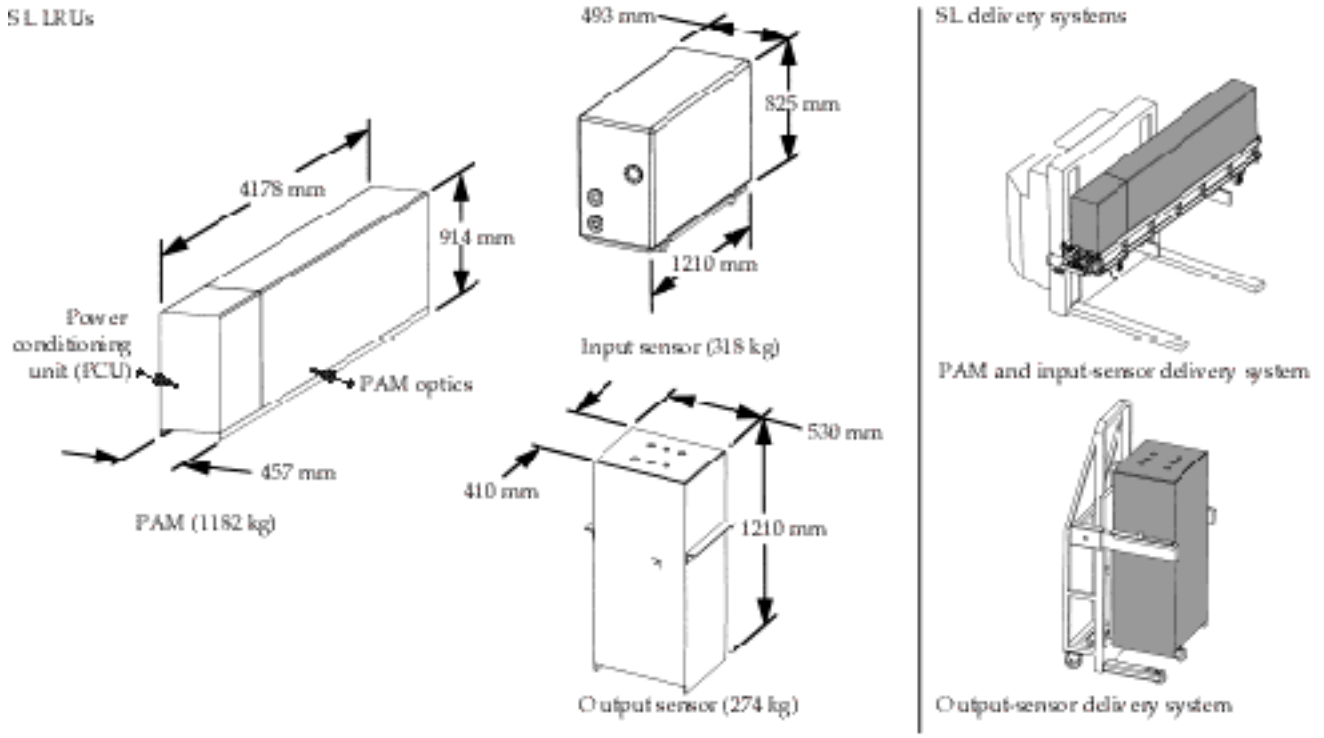

FIGURE 9. Three side-loading LRUs and two side-loading delivery systems. (40-00-0997-2086pb01)

compliance with LLNL seismic safety standards. We will support the specification and procurement of the laser bay transporter.

Switchyard Delivery System

The LRU positions within the switchyard structure require access to most of the switchyard levels (Figure 10). The handling concepts use as much "off the shelf" hardware as possible to minimize complexity and increase reliability in the T&H task (Figure 11). The powered transporter is based on commercially available designs. The original concept of using bridge cranes has been changed to use monorail systems, which allows access through each switchyard level, thus minimizing floor loading requirements for the switchyard structure. The handling components, such as the shock-mounted skid assembly, may be used in other T&H efforts, reducing risk and design costs and increasing commonality.

The flexible design of the switchyard delivery system skid allows for multiple orientations of the laser mirror (LM) 4 and LM5 optics, which differ slightly in configuration and direction of insertion. The lift carriage design also adapts to safely support each configuration of the LM optics.

In addition to the laser mirrors, other LRUs within the switchyard include roving mirror optics, precision diagnostics, and beam dump shutters.

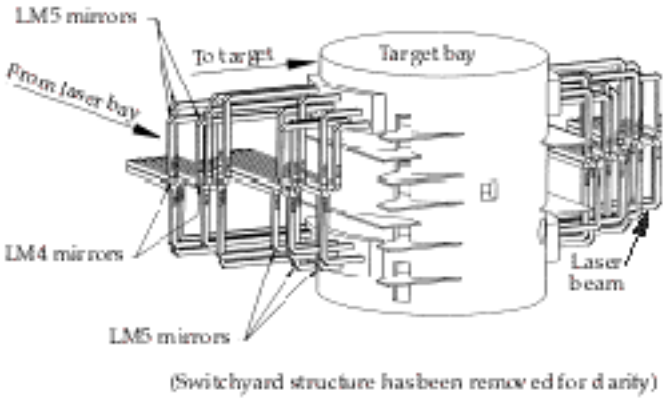

FIGURE 10. The optic positions on the switchyard levels. (40-00-0997-2087pb01)

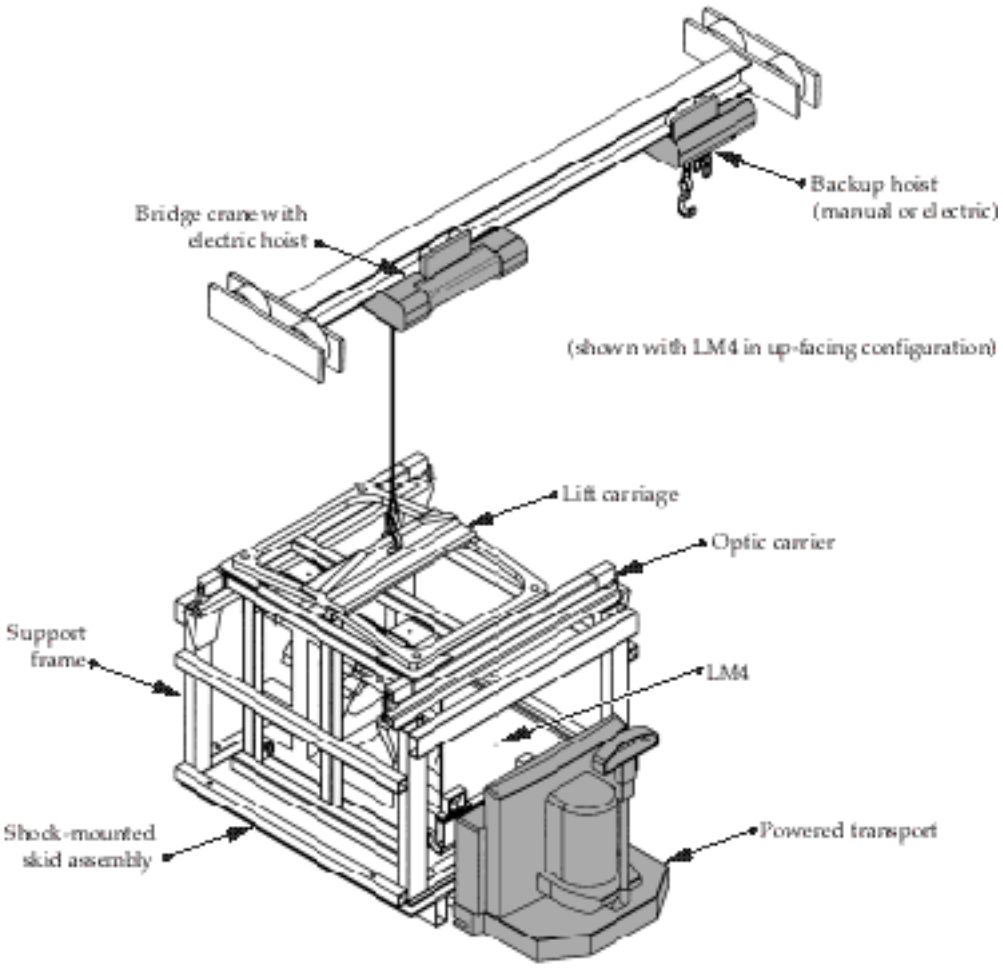

FIGURE 11. Off-the-shelf hardware in the switchyard delivery system.
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Each of the delivery systems for these LRUs uses the same transporter and skid. Uniqueness in the design is in the support frame, capturing the LRU during transport. The roving mirror LRUs also require an enclosure to preserve Class 100 cleanliness levels for the optics during transport and installation.

Title II Activities

Title II tasks include OAB transfer to delivery systems, detail design of each of the delivery systems, prototype testing of the LM4 up-facing delivery system, concept and design of a Standard Mechanical Interface-type optic enclosure for the roving mirror optics, and the determination of operating procedures for each of the handling tasks.

Target Area Delivery System

The target area optics include the following: LM6, LM7, and LM8 (Figure 12); integrated optics modules (IOMs) and several debris shields (Figure 13). The handling concepts for these optics are very similar: a skid assembly that includes a shock-mounted deck is used along with a transporter. The optics are firmly fastened to the skid deck. Shock and vibration levels are below the maximums as established by each of the LRU engineers.

Title II Activities

The Title II effort will focus on the detail design of each LRU handling system. The main emphasis will be on commonality of the systems and reliability.

FIGURE 12. Target area optics. (40-00-0997-2089pb01)

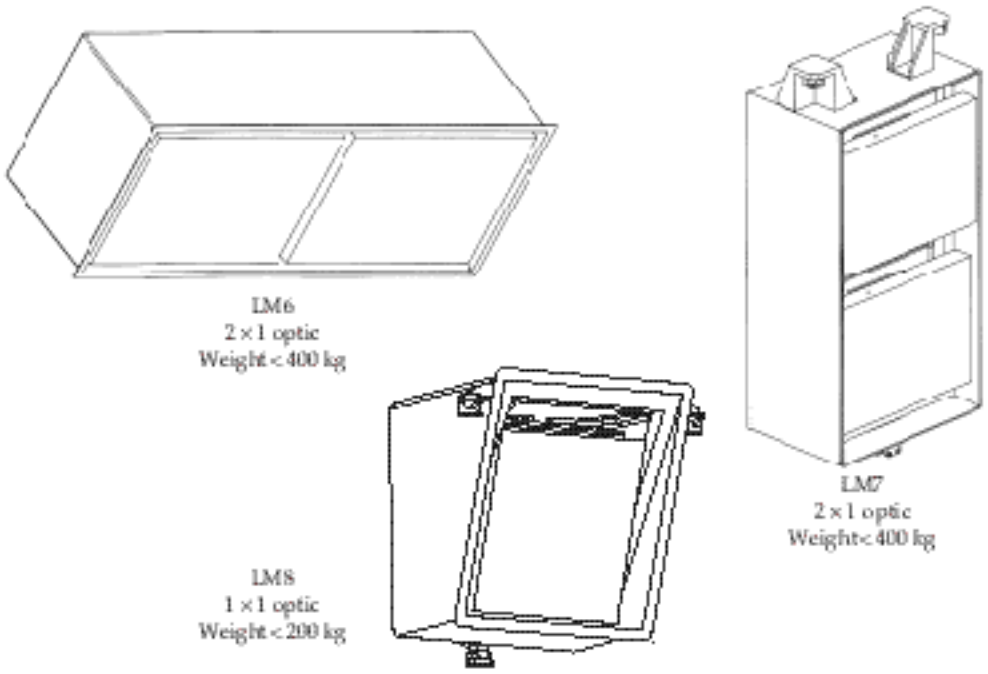
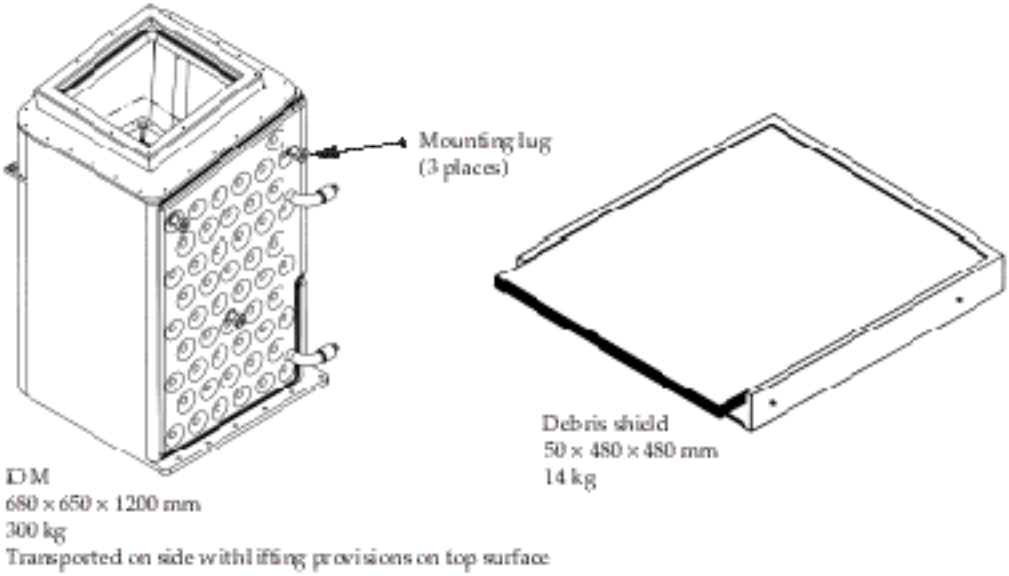


FIGURE 13. Integrated optics module (IOM) and debris shield. (40-00-0997-2090pb01)



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